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United States
Department of
Agriculture

Forest Service

**Pacific
Northwest
Region**

# Forest Pest Management

## Project Report

R6-90-01

Efficacy Evaluation of a Recommended Aerial Spray Regime to Suppress Douglas-fir Cone and Seed Insects

**A sub-study of a demonstration of the feasibility of using helicopters to apply insecticides to Douglas-fir seed orchards**

# Efficacy Evaluation of a Recommended Aerial Spray Regime to Suppress Douglas-fir Cone and Seed Insects (A Sub-Study of a Demonstration of the Feasibility of using Helicopters to Apply Insecticides to Douglas-fir Seed Orchards)

by

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## INTRODUCTION

This evaluation is part of a preliminary feasibility demonstration of aerial insecticide application technology currently operational in the Southeastern U.S. (Barry et al 1984) and potentially useful in the West. The opportunity to evaluate the aerial application of insecticides in seed orchards occurred when the Oakridge Ranger District of the Willamette National Forest requested assistance in improving the effectiveness of insecticide treatments against seed and cone insects of Douglas-fir. Douglas-fir seed for the 3,000' to 4,500' elevation zone, represented at the Heather Seed Orchard, is in short supply. The larger study of which this evaluation was a part consisted of investigating canopy penetration and deposition of insecticide sprays. A subsidiary study was to evaluate the drift of insecticide off-site. This information will be used to validate computer simulation models of spray behavior in Douglas-fir seed orchards (Curbishley and Skyler 1989 and Teske 1988). The objective of this evaluation was to determine the effectiveness of a spray regime to protect Douglas-fir cones and seed from the primary cone and seed insects. A successful series of treatments was expected to result in saving more than 75 percent of the potential good seed per cone.

With the exception of the Douglas-fir cone gall midge, Contarinia oregonensis (gall midge), there is no practical way to monitor Douglas-fir cone and seed insect population densities and predict damage to the current year's cone crop. An adaptation of Miller's (1986 a, 1986 b) survey methodology is laborious and only has application to making decisions concerning the advisability of treating horizontal to pendant cones with a systemic insecticide to suppress gall midge larvae. No survey methods are operational for the other major insects affecting Douglas-fir seed production. Unpublished data of Mike Haverty and Tim Schowalter indicate that the gall midge, Douglas-fir seed chalcid, Megastigmus spermotrophus (seed chalcid), Douglas-fir cone moth, Barbara colfaxiana (cone moth), and Douglas-fir cone worm, Dioryctria abietivorella (cone worm) are the primary cone and seed insect pests at the Heather Seed Orchard.

## MATERIALS AND METHODS

An application of azinphosmethyl(Guthion 35W) at 2 pounds active ingredient per acre was applied April 27 when the conelets were upright and receptive to pollination. The target pests were gall midge and cone moth. Subsequent applications of esfenvalerate (Asana XL) at 0.19 pounds active ingredient per acre, were applied June 7 and July 6 against seed chalcids and cone worms. Rhodamine WT was added for assessment of spray deposit on Kromekote cards and drift sampling strings.

A Bell 47G3B2 equipped with 34 D-45 nozzles at 90 degrees, calibrated to deliver 2.5 gallons per acre, was used. To apply 5 gallons of spray per acre, two passes

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over the orchard were made. The spray was delivered in a 60 foot swath at 45 miles per hour from 20 feet above the orchard canopy. The volume median diameter of the spray droplets was calculated by the methods of Yates et al (1984) to be 263.6 microns.

Experimental Design:

In this preliminary evaluation, a simple t-test was used to compare experimental parameters from the two populations. Mean numbers of seed per cone for each experimental parameter and upper and lower confidence limits for $p = 0.05$ were computed.

The test had two treatments, the insecticide regime and untreated controls; the treatment was represented by 10 single-tree replicates and the control was represented by 9 single-tree replicates. Twenty cone-bearing Douglas-firs were selected, numbered and treatments assigned to each tree randomly. Each tree had 2 upper crown, 2 mid crown and 2 lower crown cone bearing branches tagged and flagged. To address other project objectives, the spray boundary was changed resulting in the loss of one of the control tree replicates.

Design Execution:

On the day before each spray, live conelets on each sample branch were tallied. All dead conelets were removed and the cause of mortality determined if possible. Before spraying, large plastic garbage bags were placed over the sample branches of the untreated check trees. The bags were removed 4 hours after the spraying was completed.

Cone Collection and Sampling:

The cones were harvested when they reached maturity. Cones from the 6 sample branches per tree were thoroughly mixed, and a random sample of 10 were individually bagged. The proportions of sound, unfilled, and infested by M. spermatrophus were determined by examination of radiographed images of the normal extractable seeds from each sample cone. Each cone was bissected to determine the number of seeds destroyed by C. oregonensis, B. colfaxiana and D. abietivorella. If damage from other insects was present, it was recorded.

## RESULTS AND DISCUSSION

The Heather Seed Orchard was unmanaged until the last few years so large populations of pest insects likely existed in the orchard. No surveys were conducted to determine pre-treatment levels of insects. The first application, guthion, was applied when the conelets were upright and receptive to pollination. This timing coincided with gall midges and cone moths contacting foliage and conelets while mating and egg-laying. The objective was to reduce the populations before egg-laying occurred. Later emerging cone moths, seed chalcids, and early emerging coneworms were the targets of the second treatment, the first application of esfenvalerate. Later emerging cone worms were the target of the third treatment, the second application of esfenvalerate. Each of these applications was done to take advantage of the contact insecticide effects of these formulations. Because of the severe shortage of seed for the breeding zone the orchard represented, the use of untreated check areas was not acceptable to the orchard managers. Preserving seed at any reasonable expense was the management direction, thus the aggressive treatment regime.

No evidence of phytotoxicity due to treatment was seen. Complicating analysis of censuses of surviving structures (flowers, conelets, and cones) is evidence of squirrel foraging plus unexplained loss of structures. Future studies should control these variables to reduce their confounding effects.

Mean numbers of seed per cone for each experimental parameter and upper and lower confidence limits for p = 0.05 were computed. The results of the t-test on each experimental parameter indicated no differences between the treatment and bagged trees. One should not conclude that there was not a treatment effect from these insecticide applications. The use of bagged branches to represent the untreated check entailed considerable risk in not being a surrogate for truly untreated trees. It is unlikely that small, weak fliers as midges or chalcids would fly directly to untreated branches without alighting on treated branches.

Tables 1 and 2 array the experimental parameters as categories of seed. From these tables, by inspection, the results of the insecticide treatment can be determined.

Table 1. Cone Bisection Analysis to determine mean number and percent of unextracted seed in 6 loss categories.

| | Bagged | | Treated | |
|---|---|---|---|---|
| Category | Mean* | percent | Mean | percent |
| filled seed | 1.30 | 29.61 | 1.63 | 50.00 |
| empty seed | 1.22 | 27.79 | 0.72 | 22.08 |
| gall midge | 0.75 | 17.08 | 0.65 | 19.94 |
| cone moth | 0.62 | 14.12 | 0.20 | 6.13 |
| cone worm | 0.41 | 9.34 | 0.04 | 1.23 |
| chalcid | 0.09 | 2.05 | 0.02 | 0.61 |

*The mean number of seeds on one cut face of the sample cone.

Table 2. Seed accountancy based upon seed extraction and cone bisection analysis. Numbers are mean number and percent of seed per cone in each category.

| | Bagged | | Treated | |
|---|---|---|---|---|
| Category | Mean | Percent | Mean | Percent |
| total seed | 36.02 | 100.00 | 42.91 | 100.00 |
| extracted seed | 23.47 | 64.35 | 30.08 | 67.67 |
| filled seed | 17.04(17.04)# | 47.31 | 21.43 (21.43) | 49.94 |
| empty seed | 6.41 | 17.79 | 8.60 | 20.04 |
| chalcid infested | 0.02 (0.02) | 0.05 | 0.07 (0.07) | 0.16 |
| unextracted seed | 12.54 | 34.81 | 12.83 | 29.90 |
| filled seed* | 3.71 | 10.30 | 6.41 | 14.94 |
| empty seed | 3.48 | 9.66 | 2.83 | 6.59 |
| midge galled | 2.14 (1.76) | 5.94 | 2.56 (1.97) | 5.96 |
| cone moth | 1.77 (1.45) | 4.91 | 0.79 (0.61) | 1.84 |
| cone worm | 1.17 (0.96) | 3.25 | 0.16 (0.12) | 0.37 |
| chalcid | 0.26 (0.21) | 0.72 | 0.08 (0.06) | 0.19 |

* To construct these entries for subcategories of unextracted seed, the number of unextracted seed was multiplied by the percentages in these categories from Table 1.

# Numbers in parentheses are those used in calculating potential good seed per cone. The numbers of unextracted seed infested with insects were multiplied by a factor (filled seed extracted / filled seed extracted + filled seed unextracted).

Approximately 30 percent of the unextracted seed was filled and should have been extractable. There were no indications why they were not extracted. The numbers of unextracted seed infested with insects were adjusted before calculating potential good seed per cone. This was done because this amount would not have been extracted in the absence of insects so this impact should not be attributed to insects.

The potential (100 percent) good seed per cone is the sum of the seed destroyed by insects and extractable filled seed. It does not include aborted ovules, extracted empty seed or unfilled seed eaten by insects. The potential good seed per cone was 21.44 and 24.26 seed for the bagged and treated cones, respectively. The extractable good seed was 17.04 (79.5%) and 21.43 (88.3%) seeds per cone. The insect damaged seed were 4.40 (20.5%) and 2.83 (11.7%). Confidence limits on these constructed numbers are not established. Empirical deduction suggests that the treatment objective of saving greater than 75 percent of the potential good seed per cone was met.

The treatment objective was arbitrarily established knowing that efficacy of a treatment regime is dependent on insecticide toxicity, deposit on the target, and having the insecticide on target when the pest is present and vulnerable. When all three are coincident a high percentage of the insects are expected to be killed.

In a 1987 insecticide trial at the Heather Seed Orchard, there were approximately 23.0 and 23.0 potential good seeds per cone compared with 21.44 and 24.26 in 1989 for untreated and treated areas, respectively. The extractable good seed was 5.9 and 6.6 in 1987 and 17.04 and 21.43 in 1989 illustrating the difference between an insecticide treatment failure and what was accomplished in 1989. In 1988, the orchard was treated once with dimethoate by ground equipment to reduce gall midge losses. According to the seed orchard managers approximately 80 percent of the seed was lost to insects.

In 1989, severe insect damage was expected because of the previous years' large cone crops and the failure of insecticide treatments. This recent history allows one to empirically deduce that the 1989 treatment was very successful in saving seed from insect depredation.

The treatment regime reported upon is extremely aggressive and would not be recommended for all circumstances. If protection against insect depredation is warranted, the insecticide regime should be determined on a year-by-year and orchard-by-orchard basis. Results from other aspects of this study await data reduction. Reports concerning spray deposition, drift, and FSCBG model calibration are forthcoming.

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The cones were harvested when they reached maturity. Cones from the 6 sample branches per tree were thoroughly mixed, and a random sample of 10 were individually bagged. The proportions of sound, unfilled, and infested by M. spermatrophus were determined by examination of radiographed images of the normal extractable seeds from each sample cone. Each cone was bissected to determine the number of seeds destroyed by C. oregonensis, B. colfaxiana and D. abietivorella. If damage from other insects was present, it was recorded.

## RESULTS AND DISCUSSION

The Heather Seed Orchard was unmanaged until the last few years so large populations of pest insects likely existed in the orchard. No surveys were conducted to determine pre-treatment levels of insects. The first application, guthion, was applied when the conelets were upright and receptive to pollination. This timing coincided with gall midges and cone moths contacting foliage and conelets while mating and egg-laying. The objective was to reduce the populations before egg-laying occurred. Later emerging cone moths, seed chalcids, and early emerging coneworms were the targets of the second treatment, the first application of esfenvalerate. Later emerging cone worms were the target of the third treatment, the second application of esfenvalerate. Each of these applications was done to take advantage of the contact insecticide effects of these formulations. Because of the severe shortage of seed for the breeding zone the orchard represented, the use of untreated check areas was not acceptable to the orchard managers. Preserving seed at any reasonable expense was the management direction, thus the aggressive treatment regime.

No evidence of phytotoxicity due to treatment was seen. Complicating analysis of censuses of surviving structures (flowers, conelets, and cones) is evidence of squirrel foraging plus unexplained loss of structures. Future studies should control these variables to reduce their confounding effects.

Mean numbers of seed per cone for each experimental parameter and upper and lower confidence limits for p = 0.05 were computed. The results of the t-test on each experimental parameter indicated no differences between the treatment and bagged trees. One should not conclude that there was not a treatment effect from these insecticide applications. The use of bagged branches to represent the untreated check entailed considerable risk in not being a surrogate for truly untreated trees. It is unlikely that small, weak fliers as midges or chalcids would fly directly to untreated branches without alighting on treated branches.

Tables 1 and 2 array the experimental parameters as categories of seed. From these tables, by inspection, the results of the insecticide treatment can be determined.

Table 1. Cone Bisection Analysis to determine mean number and percent of unextracted seed in 6 loss categories.

| | Bagged | | Treated | |
|---|---|---|---|---|
| Category | Mean* | percent | Mean | percent |
| filled seed | 1.30 | 29.61 | 1.63 | 50.00 |
| empty seed | 1.22 | 27.79 | 0.72 | 22.08 |
| gall midge | 0.75 | 17.08 | 0.65 | 19.94 |
| cone moth | 0.62 | 14.12 | 0.20 | 6.13 |
| cone worm | 0.41 | 9.34 | 0.04 | 1.23 |
| chalcid | 0.09 | 2.05 | 0.02 | 0.61 |

*The mean number of seeds on one cut face of the sample cone.

Table 2. Seed accountancy based upon seed extraction and cone bisection analysis. Numbers are mean number and percent of seed per cone in each category.

| | Bagged | | Treated | |
|---|---|---|---|---|
| Category | Mean | Percent | Mean | Percent |
| total seed | 36.02 | 100.00 | 42.91 | 100.00 |
| extracted seed | 23.47 | 64.35 | 30.08 | 67.67 |
| filled seed | 17.04(17.04)# | 47.31 | 21.43 (21.43) | 49.94 |
| empty seed | 6.41 | 17.79 | 8.60 | 20.04 |
| chalcid infested | 0.02 (0.02) | 0.05 | 0.07 (0.07) | 0.16 |
| unextracted seed | 12.54 | 34.81 | 12.83 | 29.90 |
| filled seed* | 3.71 | 10.30 | 6.41 | 14.94 |
| empty seed | 3.48 | 9.66 | 2.83 | 6.59 |
| midge galled | 2.14 (1.76) | 5.94 | 2.56 (1.97) | 5.96 |
| cone moth | 1.77 (1.45) | 4.91 | 0.79 (0.61) | 1.84 |
| cone worm | 1.17 (0.96) | 3.25 | 0.16 (0.12) | 0.37 |
| chalcid | 0.26 (0.21) | 0.72 | 0.08 (0.06) | 0.19 |

* To construct these entries for subcategories of unextracted seed, the number of unextracted seed was multiplied by the percentages in these categories from Table 1.

# Numbers in parentheses are those used in calculating potential good seed per cone. The numbers of unextracted seed infested with insects were multiplied by a factor (filled seed extracted / filled seed extracted + filled seed unextracted).

Approximately 30 percent of the unextracted seed was filled and should have been extractable. There were no indications why they were not extracted. The numbers of unextracted seed infested with insects were adjusted before calculating potential good seed per cone. This was done because this amount would not have been extracted in the absence of insects so this impact should not be attributed to insects.

The potential (100 percent) good seed per cone is the sum of the seed destroyed by insects and extractable filled seed. It does not include aborted ovules, extracted empty seed or unfilled seed eaten by insects. The potential good seed per cone was 21.44 and 24.26 seed for the bagged and treated cones, respectively. The extractable good seed was 17.04 (79.5%) and 21.43 (88.3%) seeds per cone. The insect damaged seed were 4.40 (20.5%) and 2.83 (11.7%). Confidence limits on these constructed numbers are not established. Empirical deduction suggests that the treatment objective of saving greater than 75 percent of the potential good seed per cone was met.

The treatment objective was arbitrarily established knowing that efficacy of a treatment regime is dependent on insecticide toxicity, deposit on the target, and having the insecticide on target when the pest is present and vulnerable. When all three are coincident a high percentage of the insects are expected to be killed.

In a 1987 insecticide trial at the Heather Seed Orchard, there were approximately 23.0 and 23.0 potential good seeds per cone compared with 21.44 and 24.26 in 1989 for untreated and treated areas, respectively. The extractable good seed was 5.9 and 6.6 in 1987 and 17.04 and 21.43 in 1989 illustrating the difference between an insecticide treatment failure and what was accomplished in 1989. In 1988, the orchard was treated once with dimethoate by ground equipment to reduce gall midge losses. According to the seed orchard managers approximately 80 percent of the seed was lost to insects.

In 1989, severe insect damage was expected because of the previous years' large cone crops and the failure of insecticide treatments. This recent history allows one to empirically deduce that the 1989 treatment was very successful in saving seed from insect depredation.

The treatment regime reported upon is extremely aggressive and would not be recommended for all circumstances. If protection against insect depredation is warranted, the insecticide regime should be determined on a year-by-year and orchard-by-orchard basis. Results from other aspects of this study await data reduction. Reports concerning spray deposition, drift, and FSCBG model calibration are forthcoming.

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